SKA-LSST Synergies: ii) Clustering and lensing

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SKA

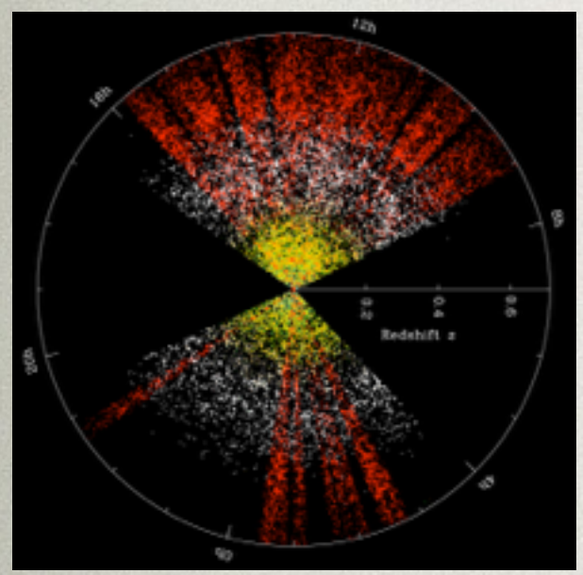
SKA Phase 1:
Frequency range: 50MHz -14GHz

Phase 1 2023; 2020 early science
Phase 2 2030

SKA-Low
~130,000 low frequency dipoles

SKA-Mid
~130 15m dishes + 64 MeerKAT

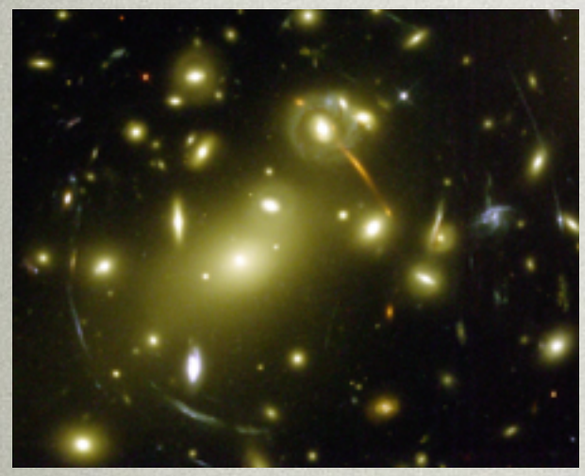
Cosmological Probes with Radio and Optical



- Source clustering

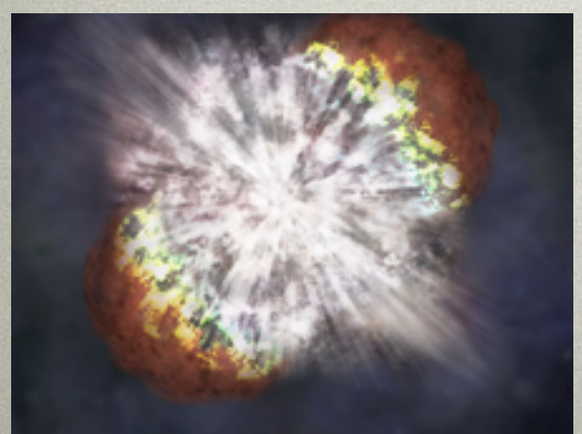
- including Baryon Acoustic Oscillations and Redshift Space Distortions

- Intensity mapping approach (SKA, DA's talk)



- Lensing

- Cosmic shear, shear-galaxy, cosmic magnification, strong lensing

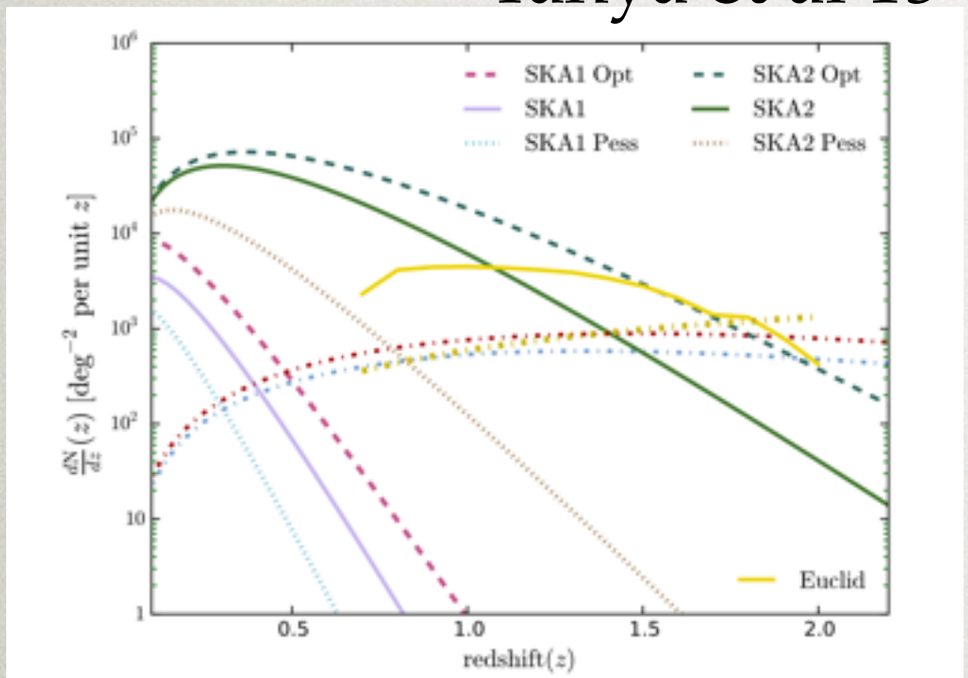


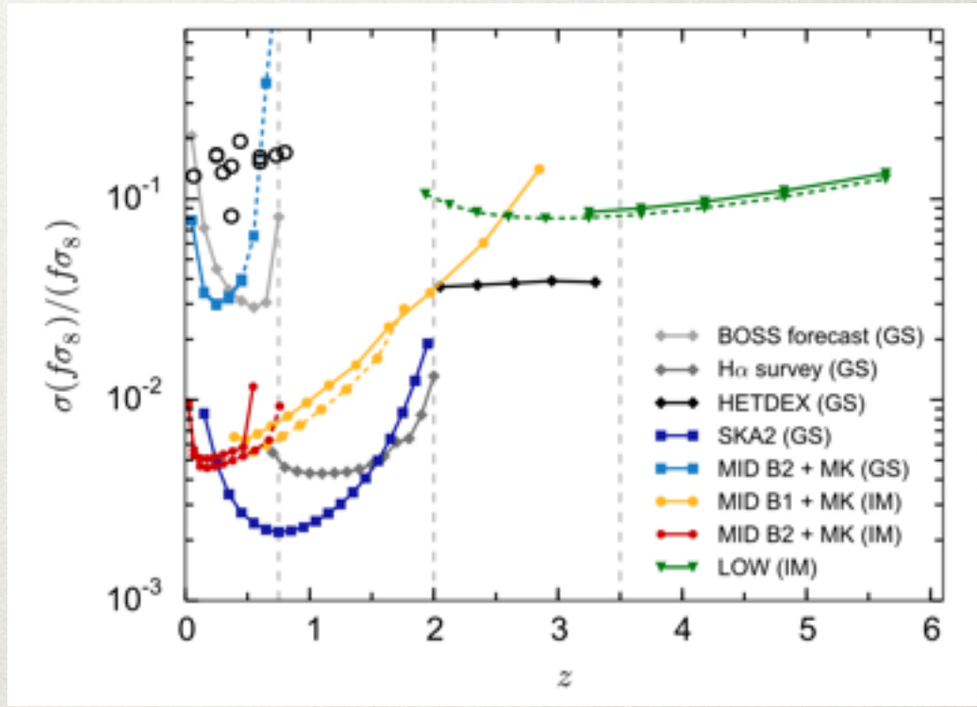
- Time domain

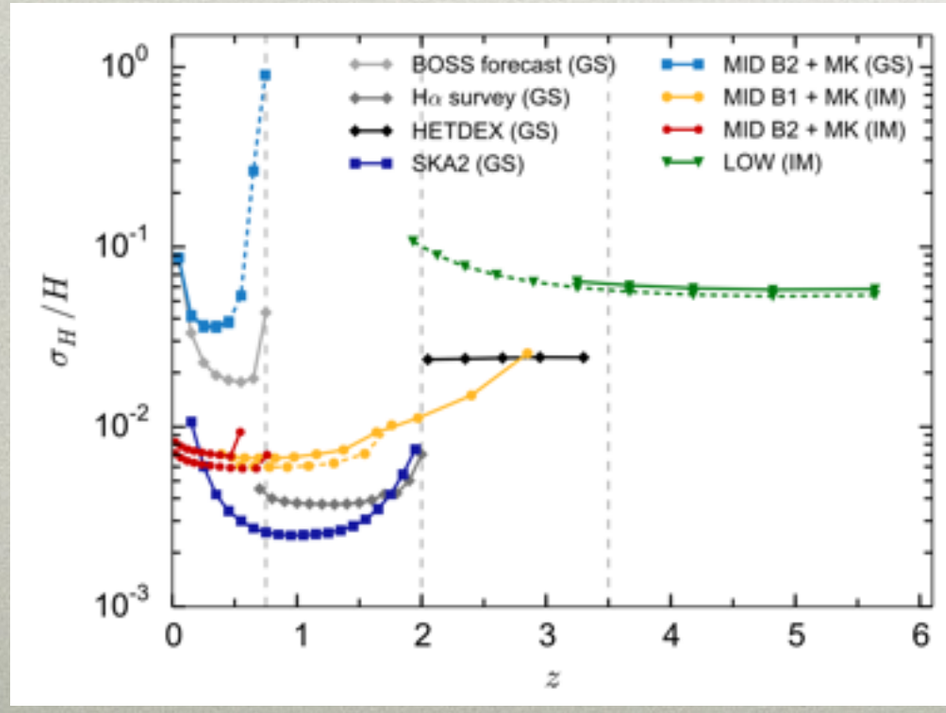
- SNe, Superluminous SNe; FRBs?

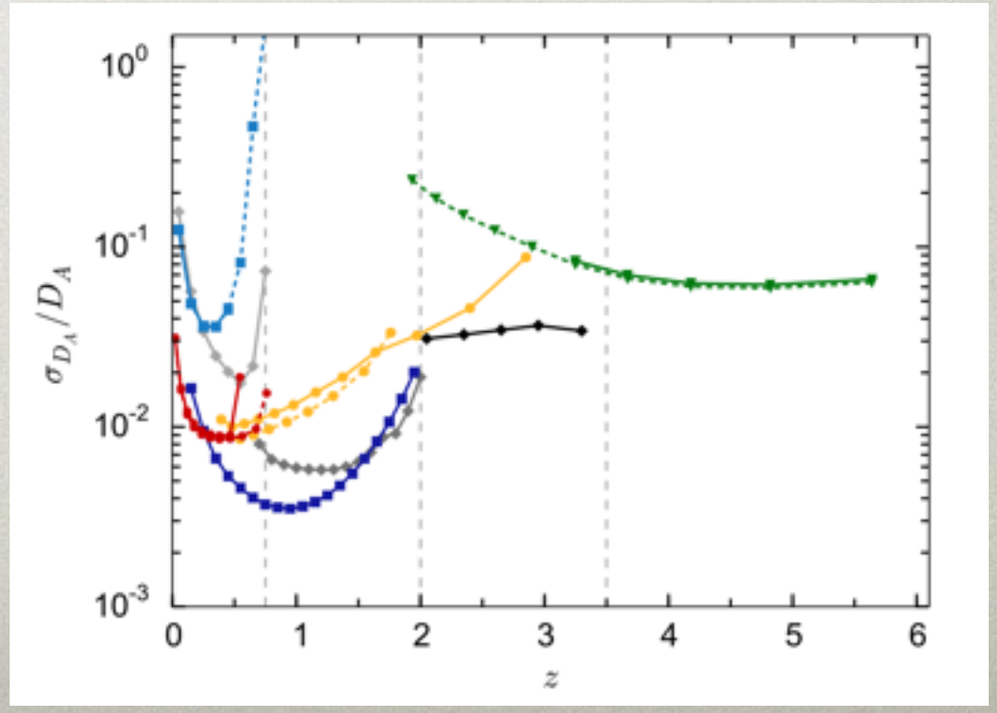
SKA offers powerful constraints

Yahya et al 15









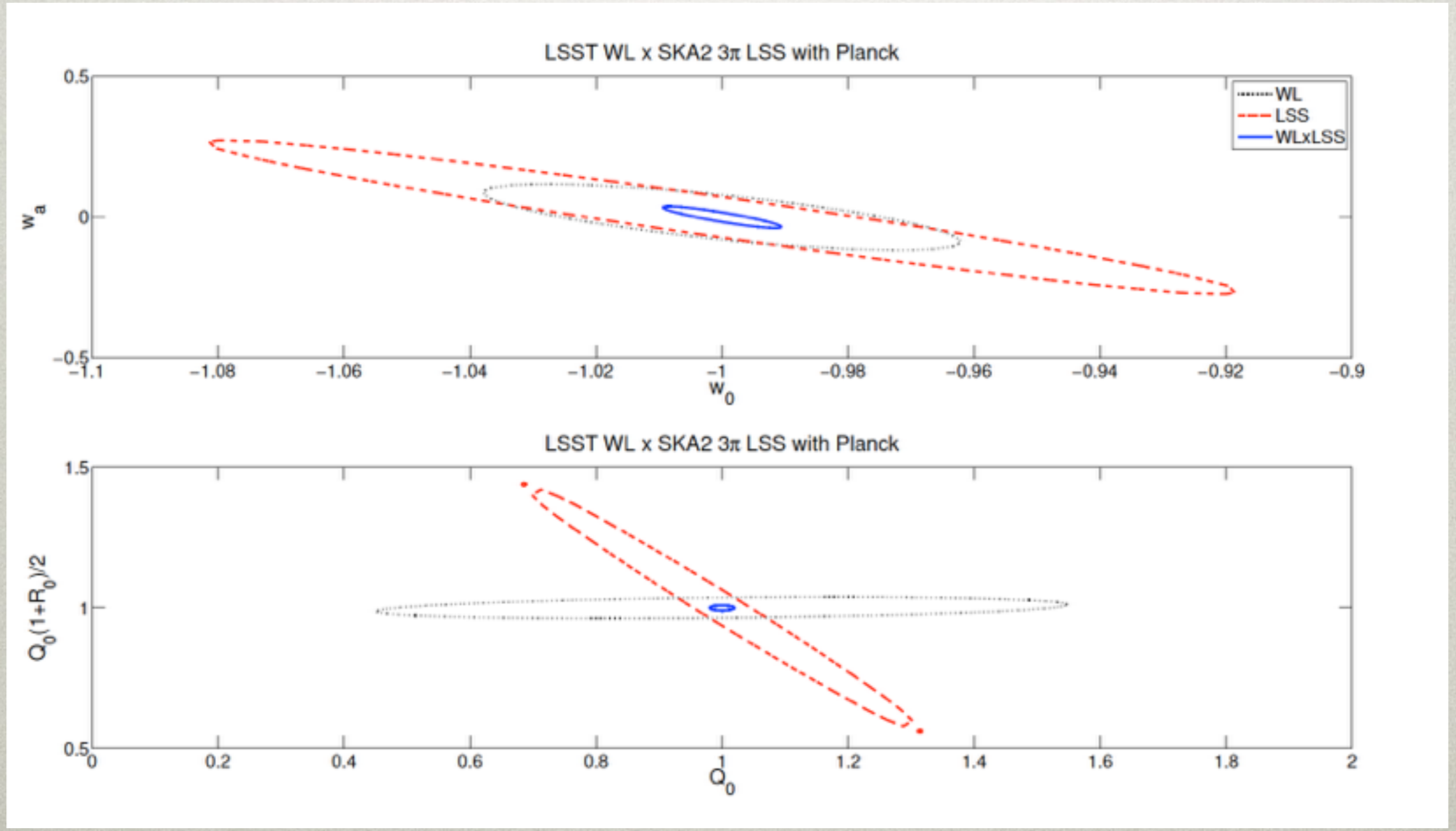
Bull 15

So what can be done in combination?

1) Combine at the end

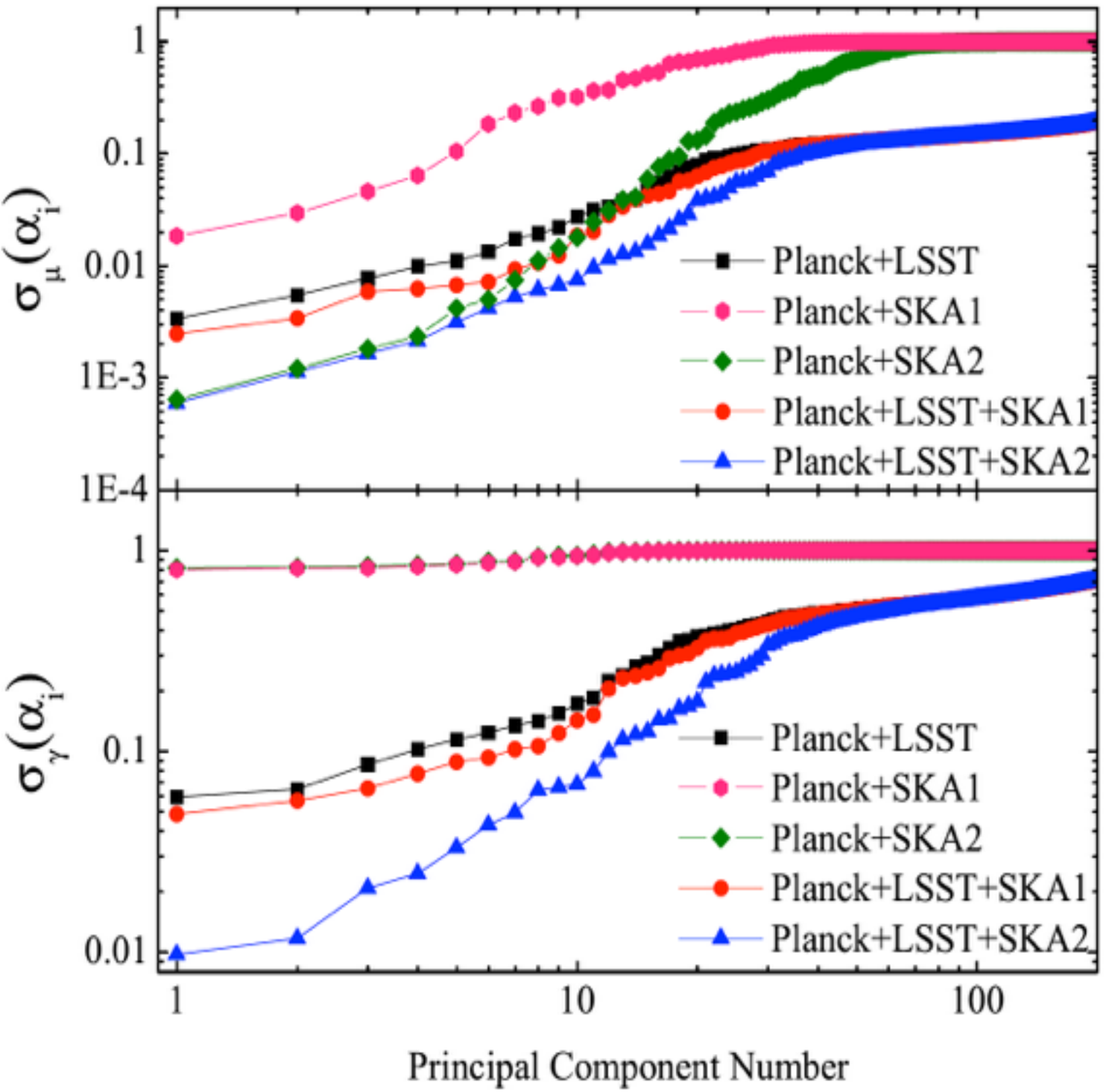
One can combine at the stage of cosmological constraints,

for all or few probes e.g. LSST lensing+SKA2 HI galaxy clustering:



Bacon et al 15

2) Combined statistics



e.g. PCA approach,
LSST lensing +
SKA HI gal clustering,
including cross-correlation

For gravity parameter g(k,z),

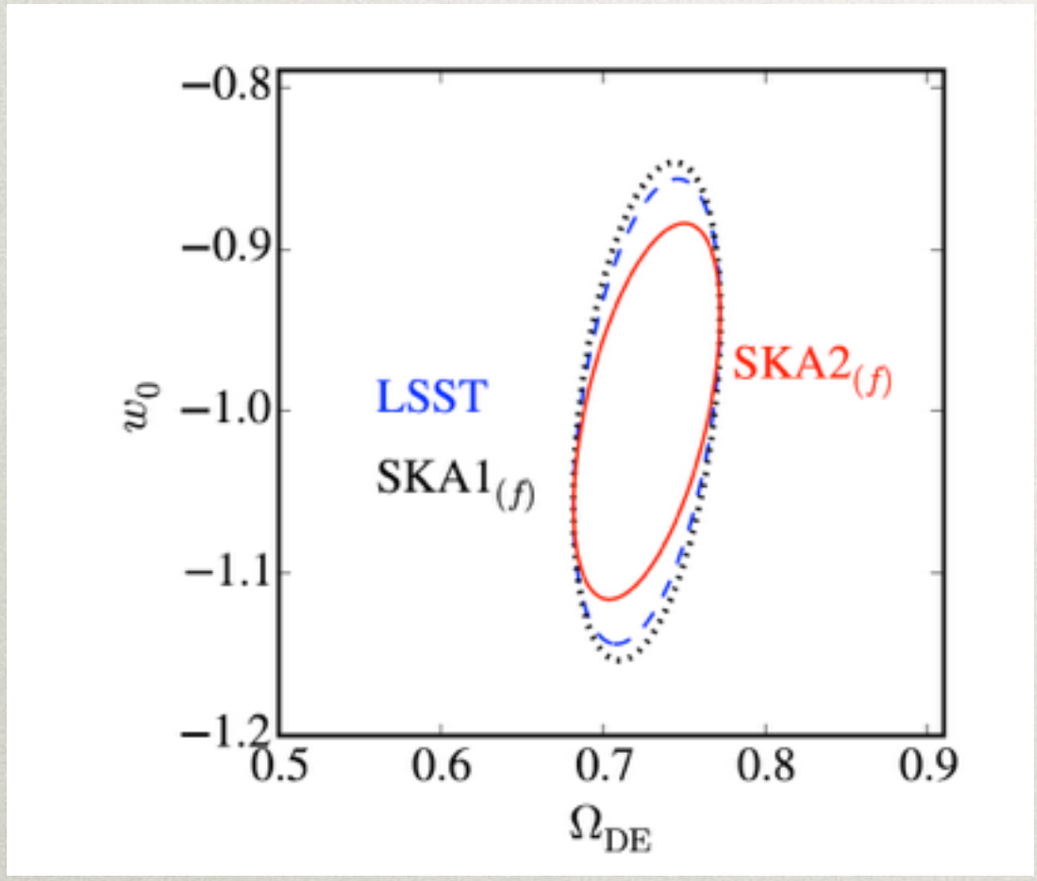
$$g(k,z) = \sum \alpha_i \, e_i(k,z)$$

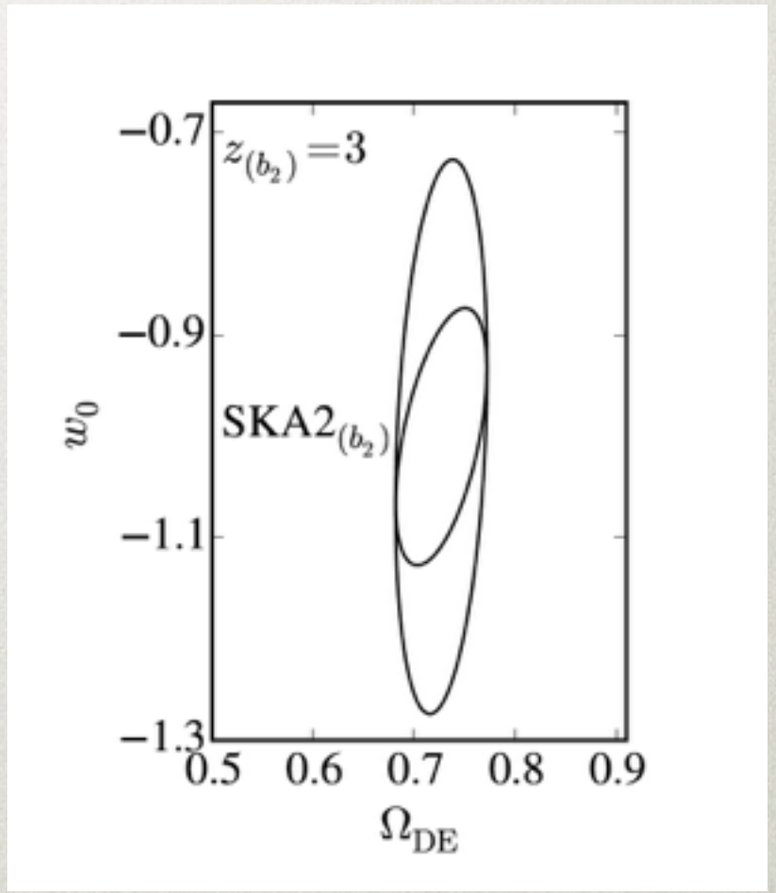
Bacon et al 15,
Zhao et al 15

3) Different parts of the Universe

One can use the differing ranges/specs to do new things:

e.g. LSST lensing+SKA intensity mapping: lensing ratios





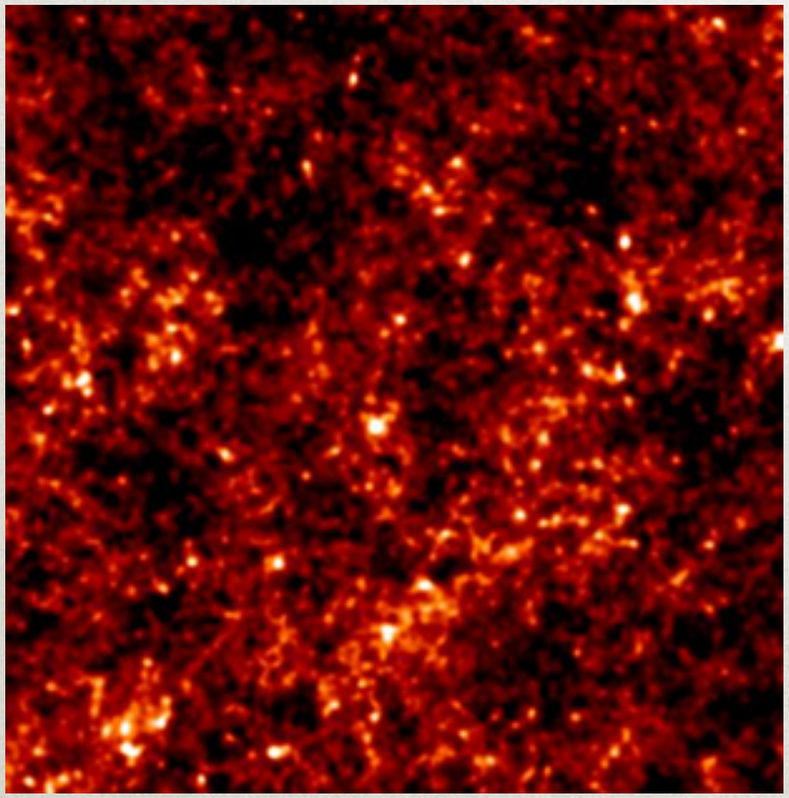
Purely geometrical measure;

Sensitive to systematics – bug and feature!

Pourtsidou et al, 2015

3) Different parts of the Universe

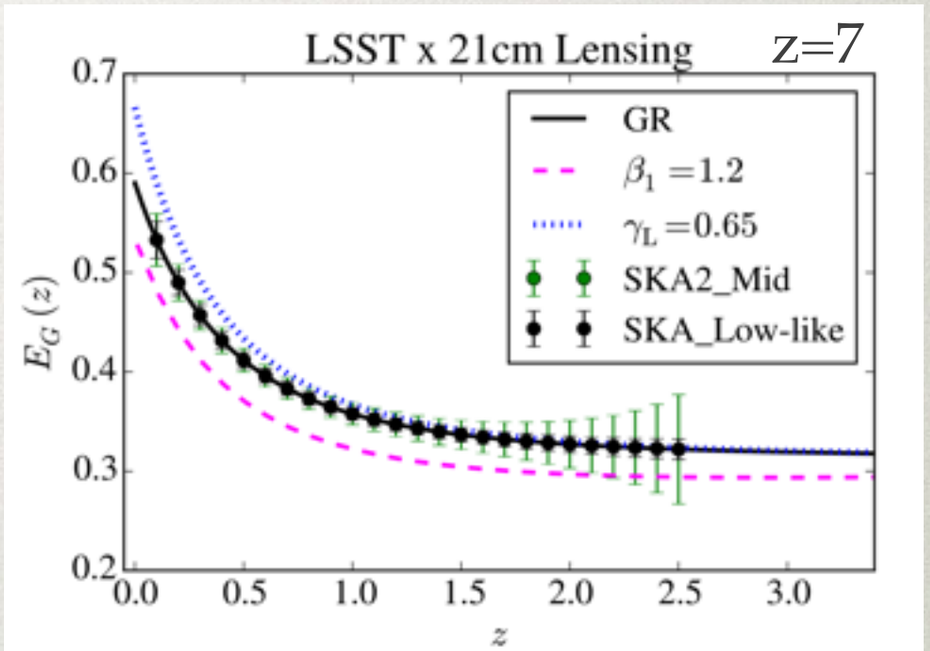
21 cm lensing at
Epoch of Reionization:



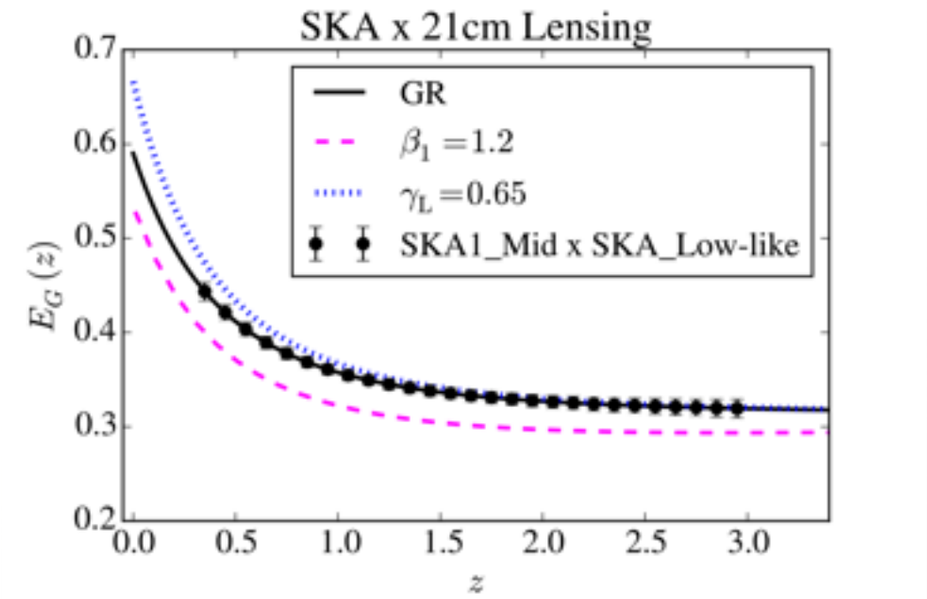
Hilbert et al 07

20′

E_G parameter,
sensitive to theory of gravity:



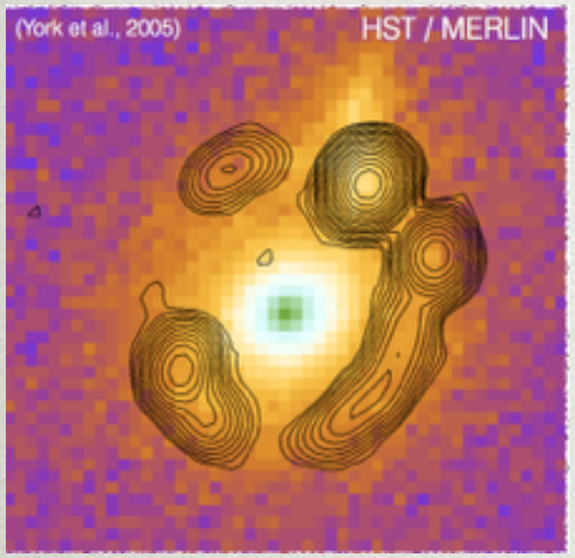
SNR =238



SNR =279

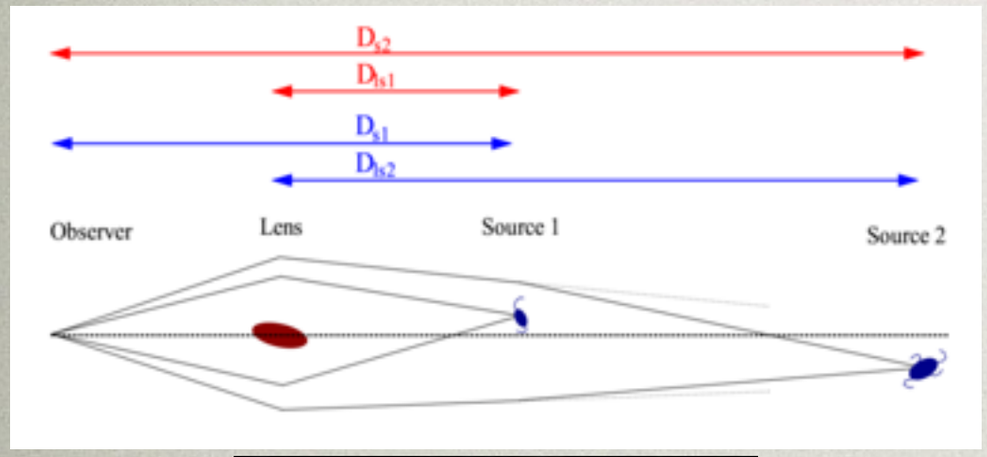
Pourtsidou 2015

4) Different wavelengths give different features

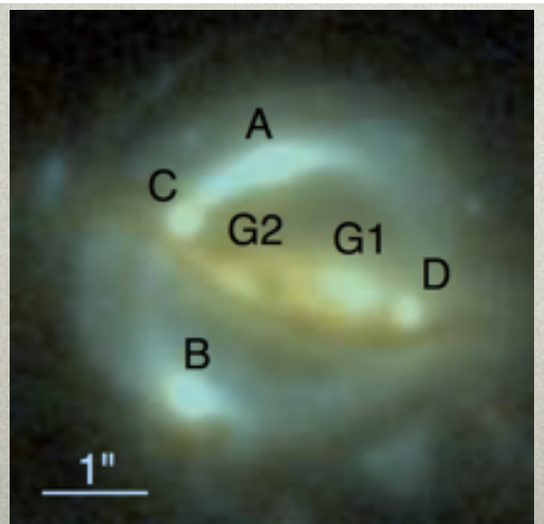


Joint selection of strong lensing systems (e.g. optical ellipticals + radio b/g sources)

10^4-10^5 lenses - examine sources at high magnification (McKean et al 15)

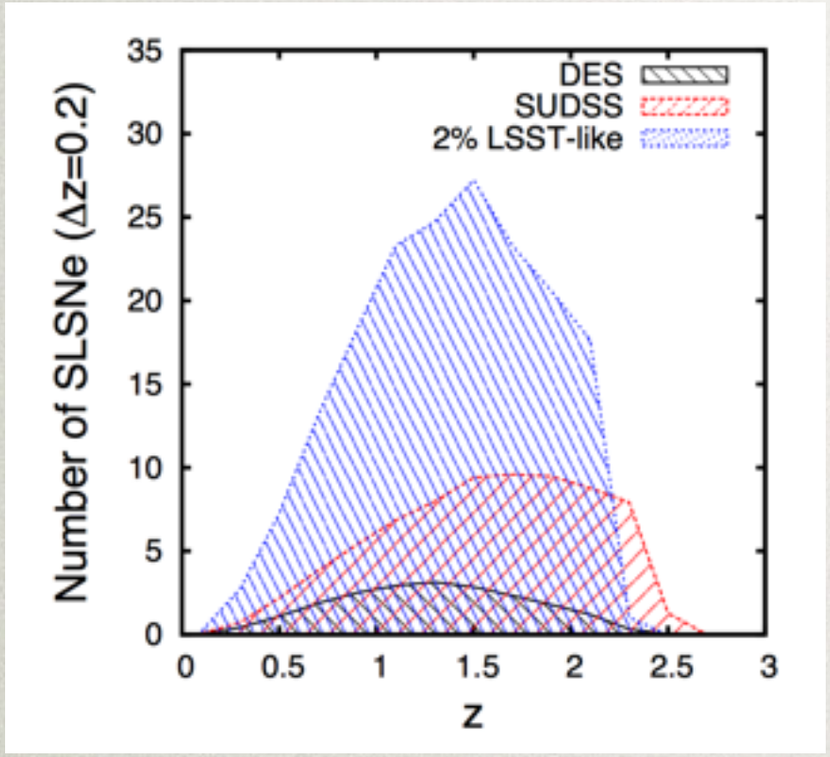


SL Cosmography (e.g. Collett & Auger 15, Collett & Bacon 16) - may find multiple arcs in optical + radio



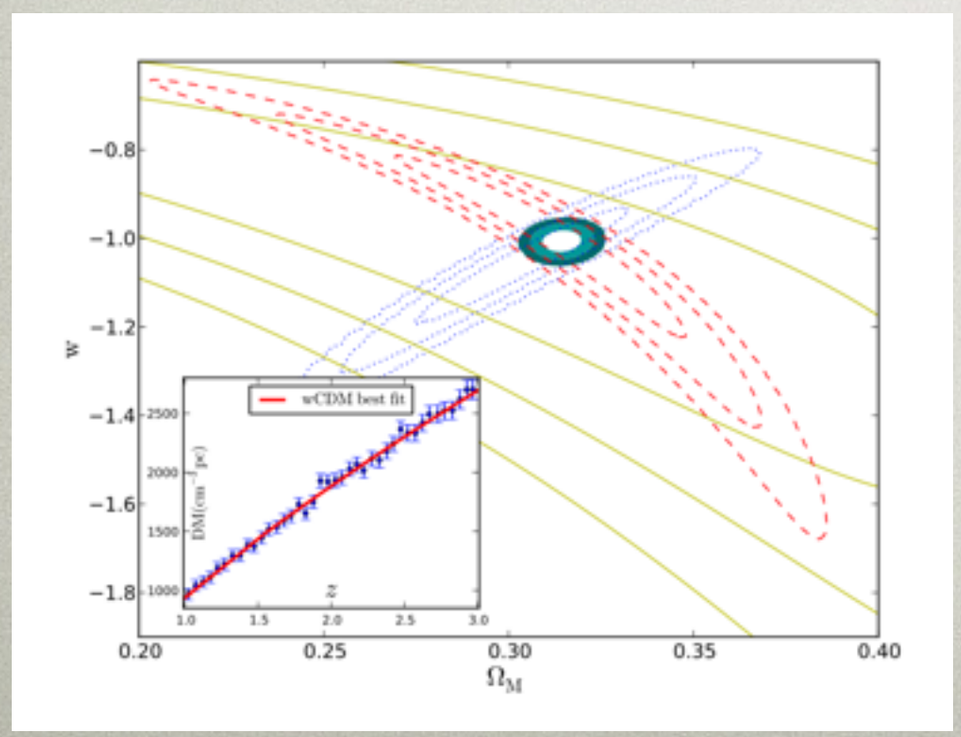
Time delays: radio quasars + optical extended arcs for mass model. (e.g. Suyu et al 2010)

4) Different wavelengths give different features



Hubble diagrams:

Optical: hundreds of thousands of SNeIa; ~10000 Superluminous SNe, possibly probing Hubble diagram to z=3 (Scovacricchi et al 16)



If Fast Radio Bursts can be made into reliable probe, they could complement SNe (Zhou et al 14) ~10^3 with SKA1

Galaxy Evolution

SKA will probe e.g. AGN and SF history over cosmic time and wide area

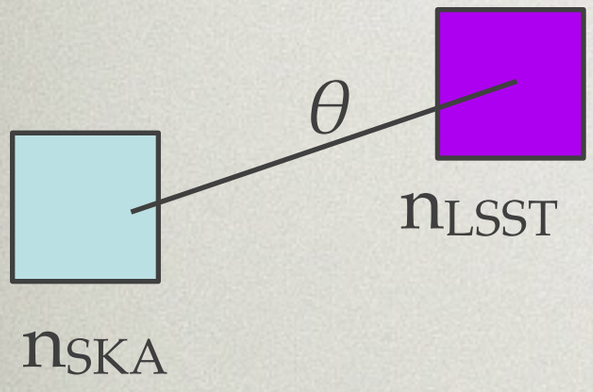
Redshifts and stellar masses from LSST

Pathway from neutral (SKA HI) to molecular gas (ALMA) to star formation (SKA continuum, LSST).

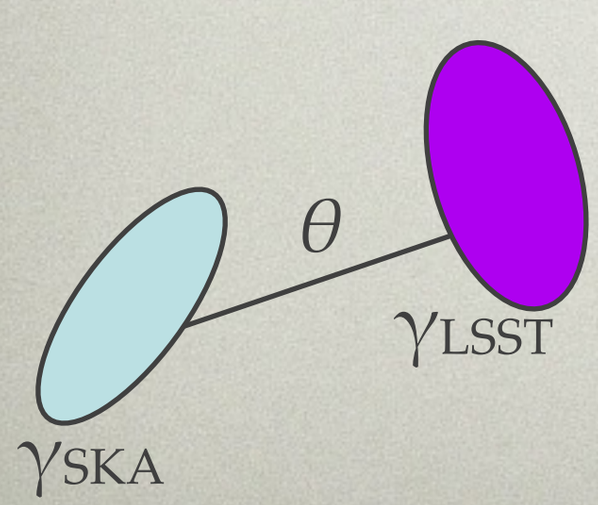
NB deep drilling fields - match with continuum, CO redshifts from SKA

5) Beating Systematic Effects

With heroic efforts, future surveys will reduce statistical error bars on cosmological parameters. Even so, we are likely to enter a systematics dominated regime, for all probes.



- Cross correlation of clustering picks out fluctuations which are not due to instrumental effects or e.g. stars.



- Cross correlation of lensing shear picks out signal which is not due to telescope systematics (Patel et al 2010, Harrison et al 2016).

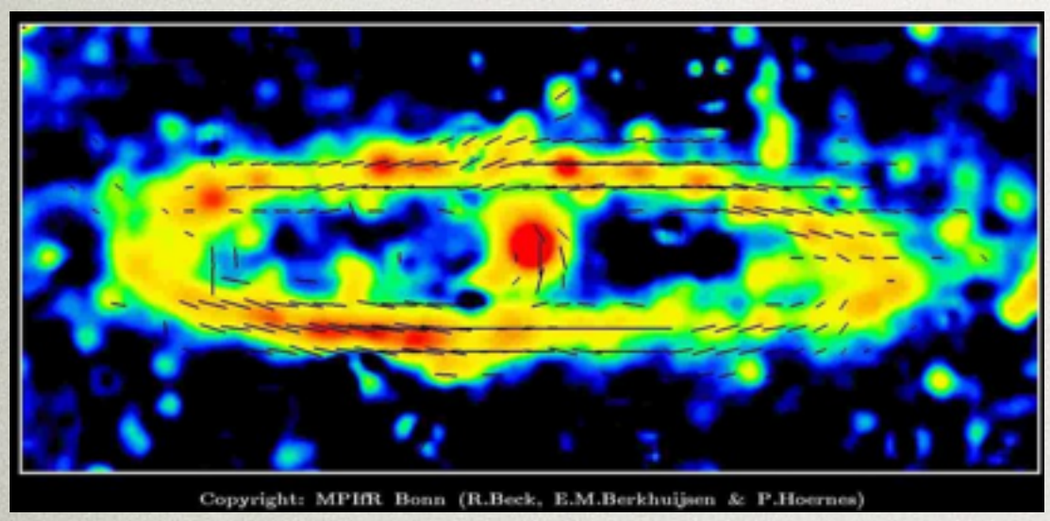
- But: radio shear is in early days.

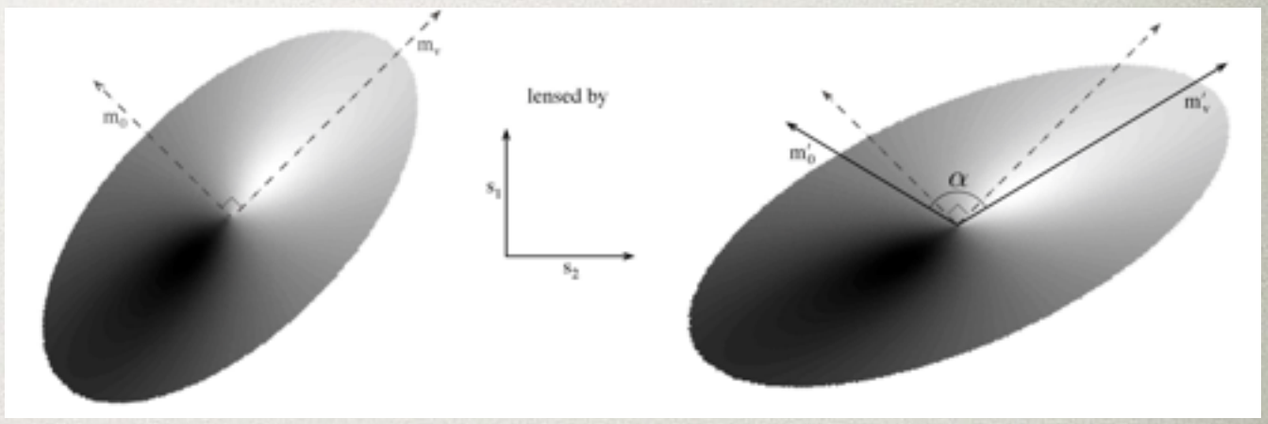
Mutual help with Redshifts

LSST is able to provide photometric redshifts for SKA continuum survey
(SKA1 1 per sq arcmin, SKA2 10 per sq arcmin, Harrison et al 16);

SKA HI redshifts can calibrate LSST photo-zs, using cross-correlation of clustering (Newman 08).

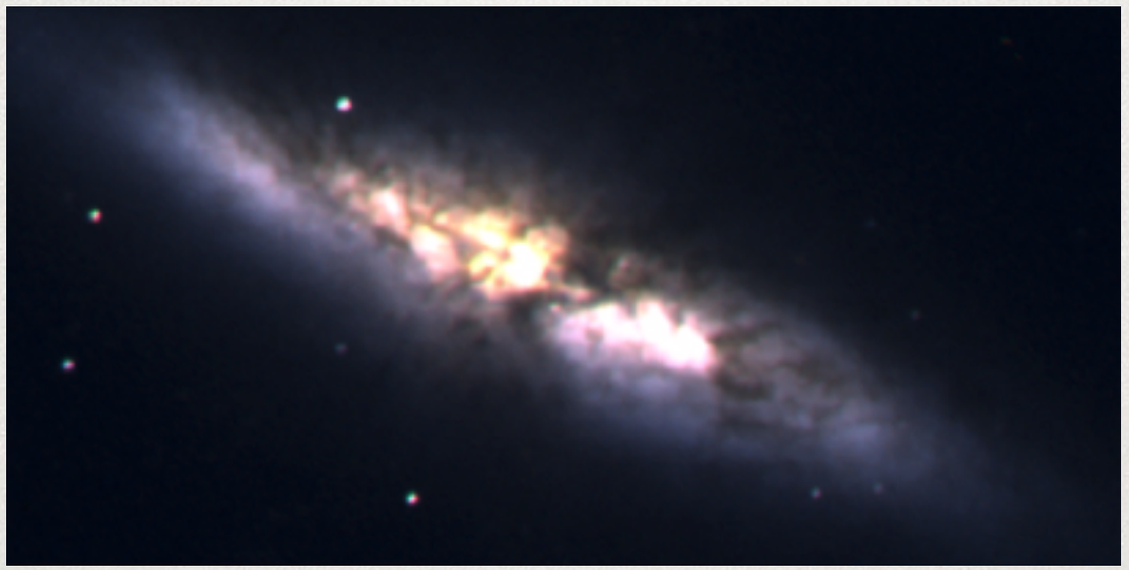
Novel Shear Information





Polarization and rotational velocity (SKA) provides info on unlensed orientation (Morales 06, Brown & Battye 11)

Colour Gradient Systematic



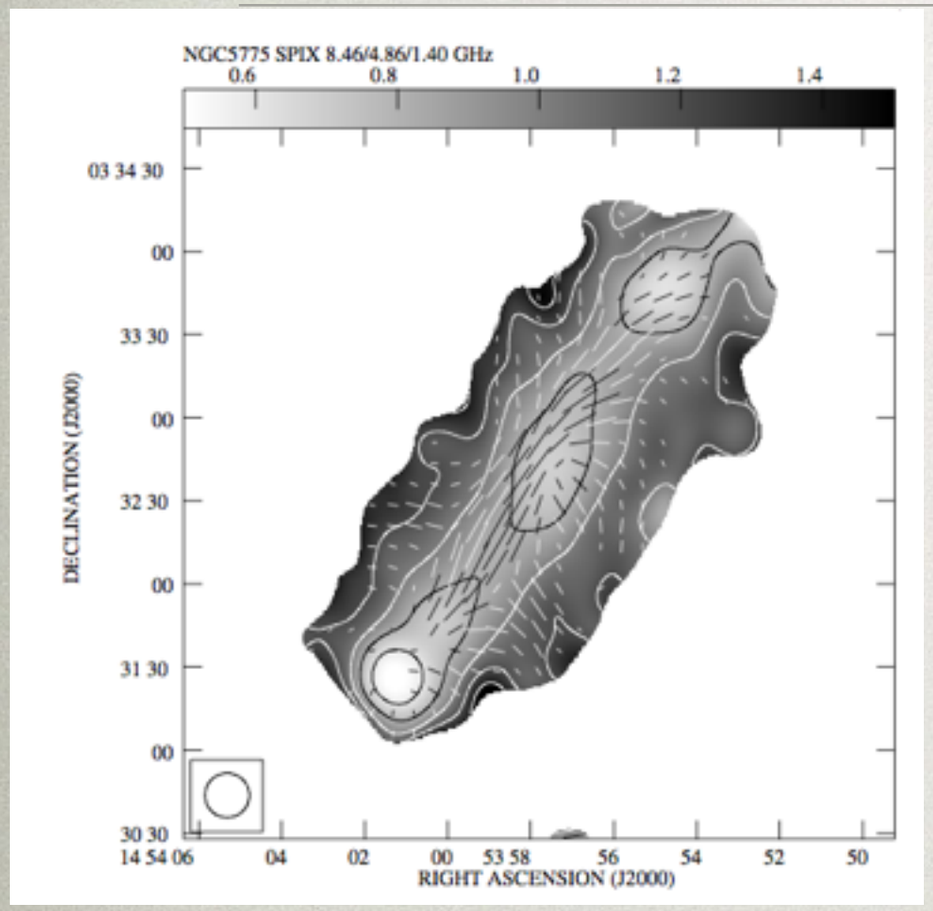
M82

Semboloni et al 2013: if PSF is function of wavelength, and galaxy has spatial variation of colour, obtain bias in shape measurement ~10^{-3}

Observations in two HST bands allow modelling of bias, reduction by an order of magnitude.

LSST+Euclid ugrizyYJH will help (but less resolution)

Colour Gradient Systematic



Soida et al 11

In radio, we keep the spectral information.

e.g. in SKA1-MID, has frequency resolution 4kHz.

Can therefore measure colour gradients and frequency dependent PSF directly, removing this key systematic.

Possible Common/joint efforts

The surveys share large computational challenges;
e.g. need $10^{9??}$ simulations for covariance matrices.

Joint shape fitting at the raw data level?

Joint LSST-SKA catalogues?

Measure many cross-power spectra between the two surveys, to constrain systematics and cosmology.

Summary

Using radio and optical together provides:

- Complementary physical constraints (different probes, spectroscopic/photometric);
- Cross-confirmation of results;
- Removal of systematics by cross-correlation (e.g. shear-shear);
- Mutual support (e.g. redshifts);
- A more complete picture (e.g. for galaxy evolution).